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E. J. STONE, M.A., F.R.S., President, in the Chair.

John Wilson Appleton, 12 Amberley Street, Toxteth Park, Liverpool; and

The Hon. Cecil Duncombe, Nawton Grange, Nawton, North Yorkshire,

were balloted for, and duly elected Fellows of the Society.

On Newton's Solution of Kepler's Problem. By Professor J. C. Adams, M.A., F.R.S.

Of all the methods which have been proposed for the solution of this problem, that which leads most rapidly to a result having any required degree of precision may be briefly explained as follows:—

The equation to be solved by successive approximations is

$$x - e \sin x = z,$$

where z is the known mean anomaly, e the eccentricity, and x the eccentric anomaly to be determined.

Suppose x_0 to be an approximate value of x, found whether by estimation, by graphical construction, or by a previous rough calculation, and let

$$x_0 - e \sin x_0 = z_0.$$

Then if

$$\delta x_0 = \frac{z - z_0}{1 - e \cos x_0},$$

and

$$x' = x_0 + \delta x_0,$$

x' will be a much more approximate value of x than x_0.

Similarly, if we put

$$x' - e \sin x' = z',$$

and if

$$\delta x' = \frac{z - z'}{1 - e \cos x'}$$

and

$$x'' = x' + \delta x',$$

x'' will be a much more approximate value of x than x'; and so on, to any required degree of approximation.

If the error of the assumed value x_0 be supposed to be of the order i, when e is taken as a small quantity of the first order, then the error of the value x' will be of the order $2i + 1 = i'$ suppose, similarly the error of the value x'' will be of the order $2i' + 1 = 4i + 3$, and so on, so that the order of the error is more than doubled at each successive approximation.

The above explains the immense advantage of this process over the use of series proceeding according to powers of e, when great precision is required in the result; since, in this latter method, the addition of a new term only increases the order of the error by unity.

The degree of rapidity of the approximation may be still further increased by the following slight modification of the above process.

Starting, as before, with the value x_0, and calling $z - z_0 = \delta z_0$, we should obtain a much more accurate value than before of the correction δx_0 to be applied to x_0, by putting

$$\delta x_0 = \frac{z - z_0}{1 - e \cos (x_0 + \frac{1}{2} \delta x_0)} = \frac{\delta z_0}{1 - e \cos (x_0 + \frac{1}{2} \delta x_0)}.$$

Now, e being supposed to be small, δz_0 is an approximate value of δx_0, and may be written for it in the small term in the denominator.

Hence, if we put

$$\delta x_0 = \frac{\delta z_0}{1 - e \cos (x_0 + \frac{1}{2} \delta z_0)},$$

$$x' = x_0 + \delta x_0,$$

x' will be a nearer approximation to the true value of x than was obtained before by the corresponding operation.

Similarly, if

$$x' - e \sin x' = z',$$

and

$$z - z' = \delta z',$$

and if

$$\delta x' = \frac{\delta z'}{1 - e \cos (x' + \frac{1}{2} \delta z')},$$

then

$$x'' = x' + \delta x'$$

will be the next approximate value of x, and the process may be continued as far as we please.

If the error of x_0 be of the order i, that of x' will now be of the order $2i+2$, that of x'' will be of the order $2(2i+2)+2 = 4i+6$, and so on, so that the degree of rapidity of the approximation is still greater than before.

If we chose to take the mean anomaly itself as the first approximate value of the eccentric anomaly—that is, if we put

$$x_0 = z,$$

we should have

$$z_0 = z - e \sin z,$$

and the value of δx_0 given by the first method would be

$$\delta x_0 = \frac{e \sin z}{1 - e \cos z},$$

while that given by the second and more accurate method would be

$$\delta x_0 = \frac{e \sin z}{1 - e \cos (z + \frac{1}{2} e \sin z)},$$

and the error of $x' = x_0 + \delta x_0$ would be of the 3rd order in the former case, and of the 4th order in the latter.

In practice, however, a much nearer first approximate value of x may be always found by inspection, and of course the smaller the error of this value is, the more rapid will be the rate of the subsequent approximations.

The methods above explained have been long known. The first method is given at p. 41 of Thomas Simpson's "Essays on several Subjects in Speculative and Mixed Mathematics," published in 1740; and Gauss' method given at pp. 10–12 of the "Theoria Motus," published in 1809, is essentially the same.

The second method, or rather the modification of the first, is given by Cagnoli in his "Trigonométrie," at pp. 377, 378 of the first edition, published in 1786, and at pp. 418–420 of the second edition, published in 1808.

Now, my object in the present note is to point out that the first method explained above is exactly equivalent to that given by Newton in the "Principia," at pp. 101, 102 of the second edition, and at pp. 109, 110 of the third edition, when Newton's expressions are put into the modern analytical form.

None of the subsequent authors, however, mentions this method as being Newton's, the unusual form in which Newton's solution is given having, no doubt, caused them to overlook it.

In the first edition of the "Principia" a modification of the method is given which was, I have no doubt, intended by Newton to be equivalent to the second method given above; but by some inadvertence, instead of the denominator of $\delta x'$ being

$$1 - e \cos (x' + \tfrac{1}{2} \delta x'),$$

when expressed in the above notation, he takes it to be what is equivalent to

$$1 - e \cos (x' + \tfrac{1}{2} e \sin x'),$$

which is only true for the first approximation when x_0 is taken $= z$.

In the second and third editions this error is corrected, but Newton contents himself with the more simple expression given by the first method.

We need not be surprised that Newton should have employed this method of solving the transcendental equation

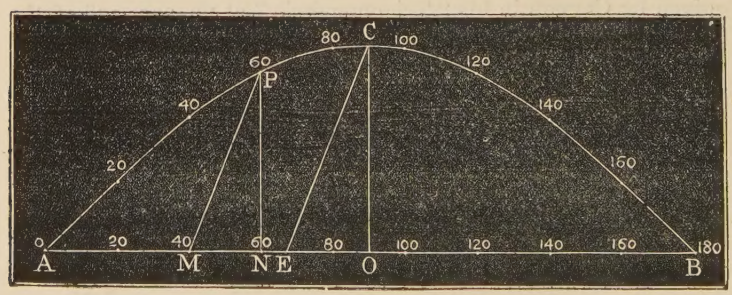
$$x - e \sin x = z,$$

since the method is identical in principle with his well-known method of approximation to the roots of algebraic equations.

For convenience of calculation, the approximate values x_0, x', x'', &c., should be so chosen that their sines may be taken directly from the tables without interpolation; and, since each approximation is independent of the preceding ones, this may always be done if x' be taken equal, not to $x_0 + \delta x_0$ itself, but to the angle nearest to $x_0 + \delta x_0$ which is contained in the tables, and if similarly x'' be taken equal to the tabular angle which is nearest to $x' + \delta x'$, and so on. In the first approximation it will be amply sufficient to use 5-figure logarithms, but in the subsequent ones tables with a larger number of decimal places should be employed.

A first approximate value of the eccentric anomaly corresponding to any given mean anomaly may be found by a very simple graphical construction, provided we have traced, once for all, a curve in which the ordinates are proportional to the sines of the angles represented on any given scale by the abscissæ.

This curve is commonly called "the curve of sines." It will be sufficient to trace the portion of the curve for which the ordinates are positive.



Let A O B be the line of abscissæ, and let A O be taken equal to O B, and let each of them be divided into 90 equal parts representing degrees of angle. Let A N be any abscissa representing the angle x, and let the corresponding ordinate N P $= c \sin x$; then the greatest ordinate will be O C $= c$, corresponding to the abscissa A O.

Suppose the curve line A P C B to be divided into 180 parts which correspond to equal divisions on the line of abscissæ A N O B.

Then if E be taken in A O so that E O $= e \times 57{\cdot}296$ divisions, or if A E $= 90 - e \times 57{\cdot}296$ divisions, and if C E be joined and P M be drawn parallel to it through P meeting the line of abscissæ in M, then A M will represent the mean anomaly corresponding to the eccentric anomaly represented by A N.

For, since the triangles P M N, C E O are similar,

$$\frac{MN}{EO} = \frac{PN}{CO} = \sin x,$$

and therefore M N $=$ E O $\sin x = 57{\cdot}296\ (e \sin x)$.

Hence M N represents the number of degrees in $x - z$, and therefore A M represents the mean anomaly z.

Conversely, if A M represents any given mean anomaly, then if M P be drawn parallel to E C, it will cut the curve in the point P corresponding to the eccentric anomaly.

By the employment of a parallel ruler we may find the eccentric anomaly corresponding to any given mean anomaly, or conversely, without actually drawing a line. For if we lay an edge of the ruler across the points E C and then make a parallel edge to pass through the point M it will cut the curve in the point P required.

Thus we may always find a first approximate value of the eccentric anomaly, without making repeated trials, whether the eccentricity be large or small.

I described this graphical method of solving Kepler's problem at the Birmingham meeting of the British Association in 1849. It is referred to in a paper by Mr. Proctor in vol. xxxiii. of the *Monthly Notices*, p. 390.

The construction is so simple that it has probably been proposed before, though I have nowhere met with it.

Note on Professor Zenger's solution of the same problem given in Number 9 of the last volume of the "Monthly Notices."

The only peculiarity in this solution is in the mode of obtaining the first approximate value employed. The subsequent approximations are carried on by means of the first method given above. Professor Zenger's process may be represented in a slightly different form as follows:—

We have

$$x - z = e \sin x,$$

and therefore

$$\sin(x-z)=\sin(e\sin x)=e\sin x\left\{1-\frac{1}{6}e^2\sin^2 x+\frac{1}{120}e^4\sin^4 x-\text{etc.}\right\},$$

or

$$\sin(x-z)=f\sin x;$$

where

$$f=e\left\{1-\frac{1}{6}e^2\sin^2 x+\frac{1}{120}e^4\sin^4 x-\text{etc.}\right\}.$$

Hence

$$\tan(x-z)=\frac{f\sin z}{1-f\cos z}.$$

Now, an approximate value of f is e, and the error in the determination of $\tan(x-z)$ if we were to put

$$\tan(x-z)=\frac{e\sin z}{1-e\cos z}$$

would be of the 3rd order in e.

If we determine f so that the error in the determination of x shall vanish when

$$x=\frac{\pi}{2},$$

we shall have

$$f=e\left\{1-\frac{1}{6}e^2+\frac{1}{120}e^4-\text{etc.}\right\}=\sin e,$$

and the approximate equation for finding $x-z$ becomes

$$\tan(x-z)=\frac{\sin e\sin z}{1-\sin e\cos z}.$$

The error still remains in general of the 3rd order in e, but the maximum error will be smaller than when f is taken $=e$.

The value of x given by this equation is readily seen to be equivalent to that given by Professor Zenger's equation,

$$\cot x=\cot z-\frac{e\operatorname{cosec} z}{1+\frac{1}{6}\sin^2 e+\frac{3}{40}\sin^4 e+\text{etc.}},$$

where we may remark that the quantity

$$\frac{1}{1+\frac{1}{6}\sin^2 e+\frac{3}{40}\sin^4 e+\text{etc.}}$$

is equivalent to

$$\frac{\sin e}{e}, \text{ or to } \quad 1-\frac{1}{6}e^2+\frac{1}{120}e^4-\text{etc.},$$

a series which converges much more rapidly than the series for its reciprocal, employed by Professor Zenger.

A still more advantageous result may, however, be obtained by determining f so that the error may vanish both when

$$x=\frac{\pi}{3},$$

and when

$$x=\frac{2\pi}{3},$$

that is when

$$\sin x=\frac{\sqrt{3}}{2},$$

so that

$$f=e\left\{1-\frac{1}{8}e^2+\frac{3}{640}e^4-, \text{ etc.}\right\}.$$

The order of accuracy of the approximation will not be altered by confining ourselves to the first two terms of this value of f, so that we may take

$$\tan(x-z)=\frac{e\left(1-\frac{1}{8}e^2\right)\sin z}{1-e\left(1-\frac{1}{8}e^2\right)\cos z}, \text{ nearly.}$$

The error is still of the 3rd order, but its maximum amount is less than before.

If f be taken

$$=e\left\{1-\frac{1}{6}e^2\sin^2 z\right\},$$

and

$$\tan(x-z)=\frac{f\sin z}{1-f\cos z},$$

the error in the determination of $\tan(x-z)$, and therefore in the determination of x, will be only of the 4th order.

There are several misprints and some errors of calculation in Professor Zenger's paper, on which I need not dwell. *True* anomaly in line 8 of the paper should be *eccentric* anomaly, and the same error occurs on p. 448.

Observations of the Great Comet (b) 1882 *made at the Cambridge Observatory with the Northumberland Equatorial and Square Bar Micrometer.*

(*Communicated by Professor J. C. Adams, M.A., F.R.S.*)

Greenwich Mean Time.	Aberration Time.	Apparent R.A.	Parallax.	Apparent Decl.	Parallax.	Comp. Star.	No. of Comp.
1882.		h m s	s	° ′ ″	″		
Oct. 25·70448	−·00842	10 5 20·019	−0·179	−17 24 19·81	+5·39	*a*	5
		19·724		34·22		*b*	5
·72215	−·00842	10 5 17·982	−0·157	−17 24 45·81	+5·47	*a*	5
		18·029		59·33		*b*	5
		c+1 43·167		*c*+11 37·78		*c*	5
·73970	−·00842	10 5 16·598	−0·132	−17 25 8·30	+5·54	*a*	5
		16·523		20·72		*b*	5
		c+1 41·831		*c*+11 17·89		*c*	5
26·69713	−·00843	10 3 54·135	−0·183	−17 47 3·22	+5·37	*d*	5
·70755	−·00843	10 3 53·366	−0·171	−17 47 15·67	+5·42	*d*	5
		e+1 8·172		*e*+ 3 29·70		*e*	5
·72058	−·00843	10 3 52·289	−0·154	−17 47 29·28	+5·48	*d*	5
		e+1 7·166		*e*+ 3 16·46		*e*	5
		f+0 49·037		*f*+ 8 19·24		*f*	5
29·71667	−·00847	9 59 25·380	−0·144	−18 54 17·89	+5·52	*g*	5
·72439	−·00847	9 59 24·524	−0·133	−18 54 23·54	+5·55	*h*	6
30·71791	−·00848	*i*+2 4·185	−0·137	*i*− 9 49·70	+5·54	*i*	5
·72769	−·00848	*j*+1 12·289	−0·123	*j*− 4 36·50	+5·57	*j*	5
·73965	−·00848	*i*+2 2·318	−0·105	*i*−10 19·85	+5·61	*i*	5
		j+1 11·034		*j* −4 49·15		*j*	5
Nov. 1·71772	−·00850	9 54 42·313	−0·127	−19 59 58·92	+5·57	*k*	7
		42·523		58·65		*l*	7
2·70519	−·00851	9 53 6·800	−0·139	−20 21 22·35	+5·54	*m*	2
·70914	−·00851	9 53 6·420	−0·134	−20 21 27·34	+5·56	*n*	3
·71242	−·00851	9 53 5·772	−0·130	−20 21 32·08	+5·57	*o*	6
5·67997	−·00854	*p*−0 13·977	−0·158	*p*− 7 6·77	+5·48	*p*	5
·70310	−·00854	9 47 59·632	−0·126	−21 25 6·20	+5·59	*q*	5
·70574	−·00854	9 47 58·761	−0·122	−21 25 3·78	+5·60	*r*	3
7·69393	−·00855	9 44 26·324	−0·128	−22 6 32·87	+5·59	*s*	5
·71300	−·00855	9 44 24·549	−0·099	−22 7 3·30	+5·66	*t*	6
		24·366		6 54·47		*s*	6
8·69769	−·00855	9 42 35·101	−0·117	−22 27 11·11	+5·62	*u*	6
		31·674		8·88		*v*	6

Greenwich Mean Time.	Aberration Time.	Apparent R.A.	Parallax.	Apparent Decl.	Parallax.	Comp. Star.	No. of Comp.
1882.		h m s	s	° ′ ″	″		
Nov. 9·68469	−·00856	9 40 43·331	−0·133	−22 47 12·04	+5·58	*w*	6
		42·582		12·41		*x*	6
·69780	−·00856	9 40 41·674	−0·111	−22 47 29·60	+5·64	*w*	6
		41·184		28·95		*x*	6
10·66723	−·00857	9 38 48·263	−0·150	−23 7 4·65	+5·53	*y*	5
		47·828		5·01		*x*	5
·67525	−·00857	9 38 47·333	−0·139	−23 7 12·86	+5·57	*y*	5
		47·221		11·61		*x*	5
14·72505	−·00859	9 30 29·332	−0·034	−24 26 0·83	+5·79	*z*	5
		29·701		25 54·95		*a*	5
17·70355	−·00861	9 23 55·545	−0·049	−25 21 9·42	+5·78	*β*	5
		γ +3 42·039		*γ* −0 47·96		*γ*	5
		δ +1 41·183		*δ* −4 37·71		*δ*	5
		ε −1 4·832		*ε* +8 57·74		*ε*	5
20·72437	−·00863	9 16 49·435	+0·008	−26 14 5·26	+5·81	*ζ*	5
		49·615		4·83		*η*	5
		49·473		5·49		*θ*	5
		ι −4 4·233		*ι* −10 42·90		*ι*	5
23·73969	−·00865	9 9 17·401	+0·057	−27 3 5·85	+5·78	*κ*	2
		λ +0 23·305		*λ* −1 12·02		*λ*	2
26·70023	−·00868	9 1 30·494	+0·014	−27 47 36·82	+5·80	*μ*	6
		30·818		37·44		*ν*	6
		ξ −1 16·764		*ξ* −4 9·79		*ξ*	6
		o −2 36·325		*o* −6 19·48		*o*	6
		π −5 18·977		*π* +2 30·53		*π*	6

Assumed Mean Places for 1882·0 *of Stars compared with the Great Comet* (b) 1882, *with Reductions to Apparent Place for the Night of Observation.*

	Right Ascension.	Reduction.	Declination.	Reduction.	Authority.
	h m s	s	° ′ ″	″	
a	10 3 37·016	+2·572	−17 33 21·66	−9·61	Lalande 19797.
b	5 33·145	+2·567	−17 24 41·42	−9·72	Argelander 279ʰ–55ᵐ.
c	3 32	+2·571	−17 36 28	−9·59	
d	4 55·923	+2·591	−18 1 18·34	−9·61	Lalande 19834.
e	2 43	+2·599	−17 50 36	−9·57	
f	3 1	+2·598	−17 55 39	−9·57	
g	9 58 42·906	+2·687	−18 52 9·82	−9·41	Argelander 356–41.
h	58 50·485	+2·687	−18 50 23·07	−9·41	„ 356–42.
i	55 45	+2·724	−19 6 8	−9·32	

	Right Ascension.	Reduction.	Declination.	Reduction.	Authority.
	h m s	s	° ′ ″	″	
j	9 56 36	+2·720	−19 11 39	−9·33	
k	53 45·720	+2·783	−19 47 32·55	−9·11	Lalande 19559, 19561.
l	57 3·070	+2·771	−19 51 13·48	−9·35	„ 19641.
m	57 20·629	+2·795	−20 15 42·58	−9·34	Argelander 356–39.
n	57 40·312	+2·793	−20 21 35·36	−9·33	„ 356–40.
o	56 9·622	+2·799	−20 23 53·12	−9·28	„ 356–37.
p	48 13	+2·910	−21 17 26	−9·07	
q	43 20·811	+2·925	−21 28 15·58	−8·83	Lalande 19275.
r	47 27·325	+2·950	−21 23 9·30	−9·02	Argelander 283–25.
s	43 8·002	+2·980	−22 7 50·76	−8·88	Lalande 19269.
t	40 51·567	+2·988	−22 6 33·66	−8·80	Argelander 283–16.
u	45 36·817	+2·999	−22 27 56·66	−9·00	„ 283–23.
v	45 47·598	+2·999	−22 24 37·63	−9·03	„ 283–24.
w	39 12·979	+3·051	−22 49 9·58	−8·81	„ 283–14.
x	39 31·702	+3·048	−22 56 31·70	−8·78	„ 283–13.
y	39 15·365	+3·079	−23 1 56·28	−8·88	„ 283–12.
z	30 28·699	+3·228	−24 19 36·54	−8·78	„ 400–138.
α	31 14·925	+3·227	−24 10 37·77	−8·85	„ 281–3 and 400–137.
β	16 16·144	+3·363	−25 27 49·35	−8·43	Melbourne Cat. 1870, 468 } Mean.
β	16 16·134	+3·363	−25 27 49·77	−8·43	Cape Cat. 1880, 4996 } Mean.
γ	20 11	+3·351	−25 20 16	−8·61	
δ	22 12	+3·345	−25 16 20	−8·71	
ε	24 57	+3·332	−25 29 58	−8·74	
ζ	21 25·600	+3·439	−26 3 57·46	−9·01	Argelander 290–129.
η	24 26·772	+3·428	−26 4 36·37	−9·11	Melbourne Cat. 1870, 474.
θ	24 40·192	+3·428	−26 4 23·14	−9·11	Melbourne Cat. 1870, 476.
ι	20 50	+3·441	−26 3 13	−8·99	
κ	5 57·944	+3·578	−26 57 34·26	−8·79	Argelander 352–179.
λ	8 51	+3·568	−27 1 45	−8·89	
μ	5 27·425	+3·668	−27 42 9·78	−9·22	Argelander 352–178.
ν	8 36·369	+3·657	−27 49 6·43	−9·29	„ 352–184.
ξ	2 44	+3·676	−27 43 18	−9·11	
o	4 3	+3·673	−27 41 8	−9·17	
π	6 46	+3·663	−27 49 58	−9·23	

Mean Places for 1882·0 *from other sources, not used in deducing the Comet's place.*

	h m s	s	° ′ ″	″	
g	9 58 42·248	+2·687	−18 52 12·35	−9·41	Lalande 19696.
h	58 50·307	+2·687	−18 50 23·72	−9·41	„ 19699.
t	40 51·344	+2·988	−22 6 28·81	−8·80	„ 19209.
u	45 36·905	+2·999	−22 27 53·31	−9·00	„ 19338.
w	39 13·433	+3·051	−22 49 10·45	−8·81	„ 19153,
	39 31·886	+3·048	−22 56 30·72	−8·78	„ 19164.
y	39 14·234	+3·079	−23 1 54·37	−8·88	„ 19154.

The observations were made and reduced by Mr. Graham.

On Photographs of the Great Comet (b) 1882. By David Gill, LL.D., Her Majesty's Astronomer at the Cape of Good Hope.

I have obtained photographs of the Great Comet of this year by attaching to the declination-axis-counterpoise of the 6-in. Grubb Equatorial an ordinary camera with a rapid portrait-lens by Dallmeyer of about $2\frac{1}{2}$ inches aperture and 11 inches focal length.

The attachment was such that any motion given to the telescope tube was common also to the camera. During exposure the image of the comet's nucleus was kept upon the intersection of two webs of the filar micrometer by means of clockwork, aided by the fine slow motions in R.A. and Declination.

In Photograph 3 (which is the most perfectly focussed) the photographic images of the neighbouring stars are elongated in the direction of the comet's motion.

I am indebted to Mr. E. H. Allis, Photographer, Mowbray, for the loan of the camera in question, and for his assistance in the work. I was too much occupied with the observations of *Victoria* and *Sappho* to be able to turn my attention to photographing the comet till after Oct. 11, when the *Sappho* observations were finished.

The successful photographs that have been obtained are:—

No. 1. 1882 Oct. 19^d 15^h 45^m Cape M.T., Exposure 30^m.
No. 2. 1882 Oct. 20^d 15^h 30^m „ „ 1^h.
No. 3. 1882 Oct. 21^d 15^h 40^m „ „ 40^m.

Of these photographs paper copies are enclosed. After Oct. 21 the work was interrupted by moonlight, but it will be resumed at next new Moon.

With more sensitive plates and longer exposure I do not doubt that photographs may be obtained for some time to come.

There is a very marked difference between the photographic magnitude and the apparent magnitude of stars. There is also an apparent difference in the photographic magnitudes caused by errors in the correction of the spherical aberration of the lens,

giving longer disks in one part of the field than in another. But there is no real difficulty in identifying all the photographed stars.

Photograph No. 2, particularly in the original negative, shows the curious envelope extending 2° beyond the head. It is less distinctly seen in Photograph 3.

This preliminary communication will afterwards be supplemented.

Royal Observatory,
Cape of Good Hope:
1882, *Oct.* 31.

[Since the foregoing paper was received, Mr. Gill has forwarded to the Society three additional photographs of which the following are the particulars:—

No. 4. 1882 Nov. $7^d\ 14^h\ 42^m$ Cape M.T., Exposure $1^h\ 40^m$.
No. 5. 1882 Nov. $13^d\ 14^h\ 0^m$ „ „ $1^h\ 20^m$.
No. 6. 1882 Nov. $14^d\ 14^h\ 15^m$ „ „ $2^h\ 20^m$.]

Observations of the Great Comet (b) 1882, *made at Auckland, New Zealand.* By J. T. Stevenson.

(*Extract from a letter to the Rev. T. W. Webb.*)

. . . I have the pleasure of now sending you a few particulars of the beautiful comet at present visible here. . . . I will begin with the head, which to me appeared at first nearly equal to a first-magnitude star, and, I may add, was seen in New Zealand in broad daylight when it was in perihelion.

I find that when viewed in the telescope the head appears just like a double star, when the power is not sufficient to separate the disks; of course I do not mean that the head is double, but it is elongated in an east and west direction, which is at present the direction of the comet's motion. On the 5th instant and once before I saw a *minute* point in the nucleus which glowed brightly.

The Dark Space behind the Head.—I notice what seems rather remarkable in the dark space: namely, the fact that whereas I am almost positive in other comets which I have seen that the dark space was broad, yet in this, the most brilliant one seen for many years, this space is very narrow. I may mention also that the head appeared slightly inclined towards the axis of the tail, and that the dark space is not directly behind, but as if the head were a little north of the axis of this space in the tail.

The Tail.—This is grand in the extreme; I have never seen anything equal to it. At the extremity it is at least several times broader than the Moon's apparent diameter. I can see the faintest stars visible through even the thickest portion of it. With a small glass I can trace plainly the dark space running up through it from the head; and here I notice another peculiarity—namely, that this space is not central in the tail, but divides it into two unequal portions, the northern of which is much broader than the other. Up to October 6, on the occasions

on which I observed, there was also seen a fainter tail extending from the north part of the head and reaching as far as the brighter one; with the naked eye the northern part of the tail was seen to be *darker* than the other parts, and it is this part which I consider the second tail. I was particular in trying to trace it right down to the head, as I had a suspicion that it had a square-shouldered aspect (I might call it) where it joined the nucleus; but of this I was not sure.

Yesterday morning, however (Oct. 6), on looking at the comet, which was then very low, I was surprised to find that the fainter portion of the tail had extended itself on both sides of the head and appeared as a second tail *pointing towards the Sun*. I traced it fully two degrees beyond the nucleus—that is, in a direction contrary to the brighter tail.

I am aware that the nuclei of some comets are of considerable extent sometimes, but I do not think what I saw on this occasion could be considered any part of the nucleus. I may state that the finder of the telescope showed this appearance also, while in the telescope itself the region in front of the nucleus was misty and ill-defined. I had not noted this mistiness on any former occasion. I noticed particularly that this fainter tail made a small angle with the direction of the brighter one. There are only two ways in which I can account for this appearance not being noted before: either that the fainter tail is really expanding, or else that the waning Moon, or else a particularly fine morning, enabled greater detail to be visible.

Oct. 10.—I have longed to get another view of comet before the mail leaves, and after two days cloudy weather I succeeded this morning.

I found that the faint tail had now extended itself sunwards for (I think) more than four degrees. I again suspected that it was not quite parallel with brighter one, but am not sure on this point. I have noticed all along the bright tail is longer on its southern side, and also that the extremity of tail has a dark space which splits that portion nearly in two. . . .

The observations were made with a $6\frac{1}{2}$ Reflector by Calver.

Postscript by the Rev. T. W. Webb.

In addition to the corroboration which Mr. Gill has afforded with regard to this remarkable phenomenon, I beg permission to mention that I have since been informed by a gentleman named Jackson, at Constantinople, that on the 2nd or 3rd, as he believes, of October, he saw the same appearance with a 4-in. object-glass as "very faint parallel rays of light stretching from the head of the comet towards the Sun;" and that at a still later date I have been favoured with a communication from Professor Schiaparelli, in which he mentions this and other still more remarkable peculiarities as observed especially by himself, and in part by Schmidt, at Athens.

Hardwick Vicarage:
1882, Nov. 18.

Observations of the Great Comet (b) 1882, *made at the O'Gyalla Observatory, Hungary.* By Dr. N. de Konkoly.

The comet, when first observed, had already lost much of its former brightness, and until November 1 all observation was prevented by continuous clouds and rainy weather. Since that time I have seen it only once between clouds, but observations then were too difficult to make. Our moist climate, together with a considerable diminution in the brightness of the comet, gives but little hope for further observations.

The observations were made on November 1, 17^h Mean Time, with the 6″ Refractor of Merz, the view from the $9\frac{1}{2}$-in. Merz Refractor being limited by the dome of the 6-in. and by trees.

In the telescope the head of the comet was very remarkable. Its oblong nucleus sharply defined towards the tail, showed two brighter points of light. The nucleus appeared of a pretty strong yellow colour, while the coma was a little greenish. The tail was considerably curved upwards, and the edge turned towards the horizon was much brighter and better defined than the other. A radiation from the nucleus, which large comets generally show, did not exist, and the whole head of the comet appeared like a candlelight seen through fog. The edges, even of the nucleus, were exceedingly indefinite. The spectrum was compared with that of a Bunsen gas flame according to the method of Professor Vogel. The nucleus had a very intense continuous spectrum, the red end of which was very bright. I could not see any sodium line. The coma showed a tolerably bright comet spectrum, characterised by the hydrocarbon bands. Later in the morning the view being more open from the northern dome, the observations were made with the large refractor. I measured three of the bands, intended to measure a fourth, and suspected a fifth towards the red. Taking the intensity of the brightest band in the yellow-green as unity, the ratio of the intensities of the others is: 0·1 (?), 0·7, 1·0, 0·2, and 0·4. The first is the suspected band in the red. The following are the results expressed in wave-lengths.

		Mm.
I.	... ...	—
II.	... ...	562·0
III.	... ...	514·7
IV.	... ...	502·6 (?)
V.	... ...	472·

All lines seemed much thickened in the middle, and better defined toward the less refrangible end of the spectrum, while fainter toward the violet. The measurements of the spectrum of the Bunsen flame gave the following results:—

	Edge.	Maximum.
I.	610·0	596·2
II.	560·2	556·9
III.	514·7	513·1
IV.	472·2	469·9
V.	—	431·4

The little discordance between the two spectra perhaps may be explained by the small dispersion of the apparatus employed.

O'Gyalla Observatory:
1882, *Nov.* 12.

Observations of the Great Comet (b) 1882, *made on board H.M.S. "Triumph."* By the Rev. Joseph Reed.

This interesting object was first seen and reported on Sunday, September 10. On Monday rain and clouds prevented its being seen; but on the 12th and 13th I was fortunately able to take observations to determine its R.A. and Declination, but these results are approximate, the sextant and compass being the only instruments available. Each morning, owing to banks of cloud and the increasing twilight, the comet was visible for only a few minutes before sunrise; the twilight prevented my determining the length of the tail, but it appeared to extend through an arc of two or two and a half degrees. The whole of the coma is very brilliant, the nucleus surrounded by a still brighter ring; the tail was not curved.

1882, *September* 12.

Latitude	11	12	0	N.
Longitude	24	40	0	W.
	h	m	s	
Ship's Time of Observation ...	5	22	18	A.M.
True Altitude of Nucleus ...	8	28	36	
	h	m	s	
R.A. of Comet	11	25	3	
Declination of Comet	4	10	23	S.

1882, *September* 13.

Latitude	13	54	0	N.
Longitude	24	20	0	W.
	h	m	s	
Ship's Time of Observation ...	5	11	20	A.M.
True Altitude of Nucleus ...	4	14	47	
	h	m	s	
R.A. of Comet	10	58	24	
Declination of Comet	0	54	58	

Sextant Observations of the Great Comet (b) 1882. By T. P. Parry, 4th Officer, s.s. *Almora.*

(*Communicated by Capt. H. Toynbee, R.N.*)

The observations were made in the Red Sea, off the *Dædalus* Light Ship, on October 14, 1882, at 4 A.M., app. time.

				°	′
Altitude of Comet ...	...	...		5	0
Distance from Regulus	...	...		25	25
„	Sirius	...	...	53	20
„	Procyon	...	...	46	40
„	Canopus	...	...	61	35

Observations of Comet Wells, 1882, *at Windsor, New South Wales.* By John Tebbutt.

Although this comet was detected here as early as June 15, the strong twilight prevented my seeing any stars of comparison, and it was not till the 19th that micrometer observations could be commenced. The long-continued clear weather enabled me to secure a large number of positions with the $4\frac{1}{2}$-in. Equatorial, which I trust may prove of service in the definitive determination of the orbit. The positions from June 19 to July 6 inclusive were obtained with the filar micrometer. The early set of comparisons on July 7 were also made with the filar micrometer, but the later set with a square bar micrometer. All the positions subsequent to the 7th depend on the square bar micrometer. During the early part of July the comet would scarcely bear field illumination. The differential measures are corrected where necessary for refraction, and those dependent on the square bar have had corrections applied for the comet's proper motion, which was rather rapid in Right Ascension. I have added the log. factors for parallax, p and q being the usual corrections in time and arc respectively, and P the comet's equatorial horizontal parallax. I have selected the best authorities available for the stars of comparison. The mean places have been brought up by means of the precessions calculated for the mean dates between the epochs of the respective catalogues and 1882, by employing Peters's elements; but proper motion has not been applied in any case. On the evenings of July 1 and 2 I noted stars Nos. 19 and 20 to be respectively of the $5\frac{1}{2}$ and 6th magnitude, but was not aware that the latter was the well-known variable *R. Leonis* till I came to the reductions for the identification of the stars of comparison. It could not have been far from its maximum.

Apparent Places of Comet Wells, 1882.

Windsor Mean Time 1882.	R.A.	Log $\frac{p}{P}$	N.P.D.	Log $\frac{q}{P}$	No. of Comps.	Comp. Star.
d h m s	h m s	+	° ′ ″	+		
June 19 5 38 7	7 22 19·31	8·7039	74 44 2·5	9·8036	6	1
19 6 1 56	7 22 32·79	8·7255	74 44 15·4	9·7894	10	1
20 6 14 4	7 35 54·20	8·7272	74 57 25·3	9·7872	4	2
21 6 21 11	7 48 43·47	8·7253	75 10 52·0	9·7879	3	3
21 6 21 11	7 48 43·38	8·7253			3	4
22 6 1 2	8 0 50·80	8·6986	75 25 17·7	9·8035	10	5
22 6 1 36	8 0 51·37	8·6992			8	6
22 6 28 18	✶ +1 33·41	8·7238	✶ +0 34·1	9·7881	4	7
23 6 34 10	8 12 55·92	8·7217	75 40 35·1	9·7888	6	8
24 6 21 35	8 24 9·75	8·7030			6	9
24 6 26 3	8 24 11·26	8·7074	75 56 5·2	9·7969	8	10
25 6 35 43	8 35 6·31	8·7095	76 12 19·5	9·7946	5	11
26 6 40 54	8 45 30·87	8·7078	76 28 49·7	9·7945	8	12
27 6 14 58	8 55 15·82	8·6714	76 45 20·4	9·8093	10	13
27 6 46 21	8 55 28·27	8·7068	76 45 42·0	9·7940	10	13
28 6 24 10	✶ +0 24·99	8·6754	✶ +4 25·2	9·8064	5	14
29 6 26 58	9 13 50·98	8·6721	77 19 42·8	9·8064	15	15
30 7 20 34	9 22 47·16	8·7216	77 37 33·5	9·7819	3	16
July 1 6 17 35	✶ +0 37·36	8·6453	✶ −8 36·9	9·8116	9	17
1 6 53 8	✶ +0 48 99	8·6917	✶ −8 9·2	9·7964	4	17
1 6 53 8	9 30 49·78	8 6917	77 54 23·4	9·7964	4	18
1 6 53 8	9 30 50·25	8 6917	77 54 28·5	9·7964	4	19
2 6 55 3	9 38 40 72	8·6890	78 11 37·5	9·7963	5	20
3 6 45 30	✶ −1 2·20	8·6729	✶ −0 27·2	9·8009	6	21
3 6 45 30	9 46 6·46	8·6729	78 28 24·6	9 8009	6	22
4 6 51 54	9 53 16·73	8·6765	78 45 8·9	9·7984	8	23
5 6 52 23	10 0 5·37	8·6731	79 1 42·8	9·7981	4	23
5 6 57 55	✶ +7 55·68	8·6799	✶ +0 48·7	9·7960	3	24
6 7 0 10	10 6 38·60	8·6791	79 18 12·4	9·7950	1	25
7 7 18 41	10 12 54·83	8·6968	79 34 22·3	9·7874	5	26
7 7 46 36	10 13 3 49	8·7212	79 34 40·7	9·7754	9	26
9 7 21 50	10 24 35·07	8·6955	80 5 33·4	9·7857	15	27
12 7 11 11	10 40 14·03	8·6784	80 49 46·2	9·7881	8	28
13 7 15 41	10 45 4·18	8·6824	81 4 2·3	9·7859	3	29
13 7 15 41	10 45 4·01	8·6824	81 4 3·2	9·7859	3	30
13 7 15 41	✶ −1 13·57	8·6824	✶ −5 50·7	9·7859	3	31

Windsor Mean Time 1882.				R.A.	Log $\frac{p}{P}$	N.P.D.	Log $\frac{q}{P}$	No. of Comps.	Comp. Star.
	d	h	m s	h m s	+	° ′ ″	+		
July	14	7	6 10	✶ −1 42·42	8·6698	✶ −2 46·9	9·7884	3	32
	17	7	21 45	11 2 36·83	8·6862	81 58 5·7	9·7806	10	33
	18	7	28 47	11 6 37·08	8·6934	82 10 50·5	9 7775	9	34
	19	6	56 26	11 10 23·61	8·6543	82 22 55·0	9 7863	2	35
	19	7	7 39	✶ −1 7·75	8·6692	✶ +0 30·2	9·7829	5	36
	19	7	12 26	✶ +1 16·84	8·6751	✶ +3 43·4	9·7817	4	37
	22	7	12 16	✶ −1 25·68	8·6756	✶ −4 47·0	9·7786	5	38
	22	7	13 52	11 21 15·36	8·6774	82 59 11·8	9·7782	6	39
	22	7	13 52	11 21 15·35	8·6774	82 59 11·1	9·7782	6	40
	23	7	28 16	11 24 40·63	8 6936	83 10 47·8	9·7731	6	41
	24	7	17 12	11 27 56·02	8 6823	83 21 59·3	9·7752	7	42
	25	7	17 23	11 31 6·92	8 6832	83 33 3·3	9·7740	7	43

Mean Places of the Comparison Stars for 1882·0 *with the Reductions to the Apparent Places for the Dates of Observation.*

Comp. Star.	Mean R.A.	Reduction. +	Mean N.P.D.	Reduction. +	Authority for Star's Mean Place.
	h m s	s	° ′ ″	″	
1	7 22 4·34	1·25	74 38 56·9	8·6	Lalande, 14515.
2	7 43 52·03	1·29	74 51 36·0	9·2	„ 15246.
3	8 3 29·19	1·33	75 8 19·2	9·8	„ 15939.
4	8 4 21·11	1·32	75 1 20·4	9·9	„ 15968 and 15970.
5	8 1 26·21	1·32	75 18 28·3	9·8	Wash. Cat. 1860, 3294.
6	8 1 7·07	1·32	75 17 55·8	9·8	„ 3292.
7	7 59 30	1·32	75 25	9·7	Star 8 mag., Approx. Pos. by Equatorial.
8	8 5 46·06	1·33	75 38 41 8	9·9	Gr. 7 Yr. Cat. 1864, 1019; Gr. 9 Yr. Cat. 1872, 801; Bruxelles Cat. 1876, 378.
9	8 27 45·53	1·38	75 54 41·6	10·5	Weisse, 8h, 667.
10	8 29 37·45	1·38	75 48 58·1	10·5	Bruxelles Cat. 1873, 1351, and 1876, 405.
11	8 35 47·00	1·39	76 12 14·4	10·7	Lalande, 17130.
12	8 52 57·57	1·44	76 28 7 0	11·0	Schjellerup, 1865, 3300; Bruxelles Cat. 1873, 1423; and Rad. Obs. 1874, 520.
13	8 54 22·31	1·44	76 57 58·4	11·2	Schjellerup, 1865, 3310.
14	9 4 26	1·46	77 0	11·3	Star 8 mag., Approx. Pos. by Equatorial.
15	9 14 52·34	1·49	77 15 24·7	11·5	Weisse, 9h, 270.
16	9 24 41·68	1·52	77 37 26·1	11·7	„ 492.
17	9 30 0	1·53	78 2	11·8	Star 7½ mag., Approx. Pos. by Equatorial.
18	9 34 48·41	1·55	77 53 58·0	11·8	Schjellerup, 1865, 3558.

Comp. Star.	Mean R.A.	Reduction. +	Mean N.P.D.	Reduction. +	Authority for Star's Mean Place.
	h m s	s	° ′ ″	″	
19	9 41 5·42	1·57	77 53 12·6	11·9	Radcliffe Obs. 1858, 657.
20	9 41 12·68	1·56	78 1 28·0	11·9	Wash. Cat. 1860, 4075; Gr. 7 Yr. Cat. 1864, 1201, and Wash. Obs. 1872, 216.
21	9 47 6	1·58	78 29	12·0	Star 8½ mag., Approx. Pos. by Equatorial.
22	9 52 20·12	1·60	78 28 40·5	12·0	Lalande. 19515.
23	9 52 27·28	1·59	78 58 41·9	12·1	Lalande, 19517.
,,	,,	1·59	,,	12·1	
24	9 52 11	1·59	79 1	12·1	Star 8½ mag., Approx. Pos. by Equatorial.
25	10 1 38·58	1·62	79 25 27·6	12·2	Wash Cat. 1860, 4218; Gr. 7 Yr. Cat. 1864, 1229, and Gr. 9 Yr. Cat. 1872, 956.
26	10 13 12·56	1·65	79 29 15·1	12·2	Lalande, 20021.
27	10 26 35 87	1·69	80 5 13·3	12·3	Nautical Almanac, 1882.
28	10 35 12·31	1·71	80 49 12·2	12·4	Lalande, 20630 and 20631.
29	10 42 34·07	1·73	81 9 21·7	12·4	Weisse, 10^{h}, 732.
30	10 41 12·43	1·72	81 6 55·5	12·4	,, 704.
31	10 46 17	1·74	81 10	12·4	Star 8 mag., Approx. Pos. by Equatorial.
32	10 51 22	1·76	81 20	12·3	Star 9 mag., Approx. Pos. by Equatorial.
33	10 58 55·76	1·77	82 1 36·2	12·3	Nautical Almanac, 1882.
34	11 0 2·16	1·77	82 13 31·4	12·3	Gr. Obs. 1859, 327; Rad. Obs. 1873, 560, and 1874, 634.
35	11 0 0·28	1·76	82 19 31·4	12·3	Lalande, 21261.
36	11 11 32	1·81	82 22	12·2	Star 9½ mag., Approx. Pos. by Equatorial.
37	11 9 7	1·80	82 19	12·2	Star 8½ mag., Approx. Pos. by Equatorial.
38	11 22 39	1·84	83 4	12·1	Star 9½ mag., Approx. Pos. by Equatorial.
39	11 28 52·73	1·86	83 4 9·6	12·0	Schjellerup, 1865, 4185.
40	11 31 13·31	1·87	83 4 38·5	12·0	Schjellerup, 1865, 4198; Rad. Obs. 1874, 675, and Bruxelles Cat. 1873, 1800; 1874, 959; and 1876, 661.
41	11 30 30·41	1·86	83 14 12·2	12·0	Wash. Cat. 1860, 4847; Schjell. 1865, 4196 and 4197; Bruxelles Cat. 1873, 1795, and 1875, 314.
42	11 32 59·37	1·87	83 17 2·7	11·9	Wash. Cat. 1860, 4872; Schjell. 1865, 4202 & 4203; Bruxelles Cat. 1874, 965; 1875, 318; and 1876, 666.
43	11 32 56·56	1·86	83 33 32·5	12·0	Lalande, 22079.

Postscript.

I may add that the comet (Comet *b*, 1882), two positions of which I forwarded to you by a previous mail, has since presented a magnificent spectacle in our morning sky. Between 9 and 10 o'clock on the morning of Sept. 17 I detected it without a telescope. It was then about four degrees west of the Sun and moving fast towards that luminary. The head and the tail for about a third of a degree were well seen. At $11^h\ 35^m$ A.M. on the following day I could again plainly distinguish it without optical aid simply by screening the eye from the Sun's direct rays. It was then less than a degree west of the Sun's western limb, and moving west, having obviously shortly before passed its perihelion. In a communication which appeared in the *Herald* of Sept. 19 I pointed out that if we assumed 6^h a.m. on the 18th as the time of perihelion passage of the great comets of 1843 and 1880, their apparent places from the 8th to the 18th would be nearly represented by those occupied by the visible comet. My conclusion was that the path of our present visitor was very similar to those described by the comets just referred to, and my suspicions have been confirmed by an approximate orbit completed at the Melbourne Observatory. Although the comet has been such a grand object in our morning sky for some time past, I have been unable till recently to find comparison stars in consequence of haze and bright twilight. As it possesses more than ordinary interest, I will endeavour to secure as many positions as possible.

Observatory, Windsor, N. S. Wales:
1882, *Oct.* 4.

Observation of the Transit of Venus, 1882, *Dec.* 6, *made at Glasgow Observatory.* By Professor R. Grant, M.A., F.R.S.

The ingress of *Venus* upon the Sun's disk on December 6 was well seen at the Glasgow Observatory. The sky during the early part of the day was somewhat overcast, but about one o'clock P.M. the day cleared up, and the Sun continued thereafter to shine with unclouded brilliancy until it descended beneath the horizon. My observation of the phenomenon was made with the large Equatorial of the Observatory, the object-glass of which, nine inches aperture, was reduced by a diaphragm to five and a half inches. The magnifying power used was 120. At $2^h\ 3^m\ 2^s$ Greenwich Mean Time a very slight indentation in the Sun's limb, indicative of the external contact of the planet with the Sun, was perceptible. The planet was now seen advancing

gradually over the Sun's limb, and about $2^h\ 19^m$ I began to think that the internal contact would soon occur. In this respect, however, I was deceived, for at $2^h\ 1\ 9^m\ 55^s$ the dark ligament, respecting which I had read and heard so much, was now distinctly seen. As the planet proceeded in its course the ligament became more and more elongated, and also more attenuated towards the Sun's limb, until finally, at $2^h\ 22^m\ 32^s$, the rupture of the ligament occurred, and the Sun's light immediately flowed round, leaving a sensible margin of light between the planet and the Sun's limb. I remarked that immediately previous to its disappearance, the dark ligament exhibited a rapid vibratory movement. This, however, lasted only two or three seconds. I am of opinion that the rupture of the ligament indicated the instant of the internal contact of the planet with the Sun.

During the observation I saw no trace of an atmosphere about the planet, and I similarly failed to discover any indication of the existence of a satellite revolving round it.

In consequence of the low altitude of the Sun, it presented a tremulous aspect at its limb during the time that the phenomenon was visible, and the same remark is applicable to the edge of the planet's disk. I am inclined to think, however, that the observation on the whole was made under favourable circumstances.

The external contact of the planet with the Sun undoubtedly occurred a few seconds earlier than the time above stated, but not, I think, earlier than between three and five seconds; and in this opinion I am supported by an experienced friend, Mr. Thomas Davison, who was with me during the observation.

Sir William Thomson having come to the Observatory for the purpose of seeing the planet on the Sun through the large telescope, a small Dollond of 3 inches aperture was placed at his disposal, and with this instrument, having a magnifying power of 60, he noted the internal contact to have occurred at $2^h\ 22^m\ 12^s$. No trace of a dark ligament was perceived by him.

The Observatory, Glasgow:
1882, Dec. 7.

Observation of the Transit of Venus, 1882, *December* 6, *made at Crowborough, Sussex.* By C. Leeson Prince.

The morning of Dec. 6 looked as unpromising for seeing the very interesting phenomenon which was about to happen as could well be imagined. The temperature at 9 a.m. was only 31°; the barometer was low and the wind N. Added to this the sky was so densely overcast that one of Crookes's radiometers scarcely performed one revolution per minute, and slight showers of hail, sleet, and snow were falling at intervals until noon. The first gleam of sunshine appeared at $1^h\ 40^m$, but two minutes afterwards the Sun was again obscured till $1^h\ 55^m$ by a large mass of cumulus cloud lying above some drifting scud. The Sun was obscured till $2^h\ 12^m$, when, through a break in this cloud, the Sun shone out with *Venus* having passed half her diameter upon his disk. A minute afterwards the Sun was again obscured till $2^h\ 16^m$ when the heavier clouds passed away, and I had no further serious interruption from them during the remainder of the afternoon. On account of my elevation above sea-level (825 feet) I was favoured by being situated just above some drifting scud, a dense stratum of which was passing below me; and when, now and then, a thin portion of this passed before the Sun, it rather tended to improve the definition than otherwise. From $2^h\ 16^m$, therefore, I watched very attentively the near approach of internal contact. At $2^h\ 17^m$ I first noticed the visibility of that portion of the planet still outside the Sun's disk, and which appeared to be illuminated by a brilliant silver line of light, which most distinctly marked the limb of that portion of the planet, and which was doubtless produced by the refraction of sunlight passing through the planet's atmosphere. The effect was very beautiful. At $2^h\ 22^m\ 7^s$ I noticed that the planet's disk became slightly distorted, and then apparently elongated upon the Sun's limb, so that I became somewhat perplexed how I should determine the instant of contact. This feature continued till $2^h\ 22^m\ 15^s$, when I observed the following. This shadow, or ligament, or whatever it was, *suddenly* left the Sun's limb in something less than a second of time, and gathering up towards the planet was no longer visible. It did not lengthen itself, or become narrower, or form a black drop towards the Sun, but merely disappeared, as I have before said, close to the planet. When this had happened I found that internal contact was over, and that there was a clear line of separation between the two limbs. I consider, therefore, that the above time of $2^h\ 22^m\ 15^s$ was *late*, and that actual contact had been over 3^s or 4^s, which would bring the time of contact to correspond very closely indeed with the theoretical time of contact for my Observatory, which was kindly sent me by Dr. Hind on the 3rd inst.—viz.

$2^h\ 22^m\ 11^s$. The following is a sketch of the phenomenon about $2^h\ 22^m\ 12^s$:—

I next directed my attention to the general appearance of *Venus*, now fully upon the Sun's disk, and I at once perceived that a halo of yellowish light surrounded her—it was not a *ring*, as in the case of *Mercury*, but a very diffused light, and constantly varying in breadth—now here, now there. As the planet advanced, this halo became much fainter, until at 3 p.m. it was no longer visible. There was no appearance of a satellite. The planet's surface was uniformly black, without the slightest speck of light visible anywhere upon it. At $3^h\ 30^m$ I went to my upper Observatory with the intention of watching the phenomenon down to the horizon with my 3-in. Wray Telescope. When within five degrees of the visible horizon the planet became decidedly elongated, and just at last almost linear. It was a splendid sunset—the Sun, shorn of rays and of a beautiful carmine colour, lit up some surrounding clouds with many gradations of the same tint, the effect of which was visible some time after the disappearance of the magnificent orb with its planet behind a large mass of cumulo-stratus cloud lying over the sea. It was a sight not to be forgotten by those who witnessed it. I did not take any micrometrical measures or photographs, having quite decided upon merely watching what might happen, and recording what was noteworthy.

I made use of my Tulley Equatorial, of 6·8 inches aperture and twelve feet focal length, to which I applied a Dawes' solar eyepiece with a power of 100.

The Observatory, Crowborough:
1882, *Dec.* 7.

Observation of the Transit of Venus, 1882, *December* 6. By W. E. Cooper.

I had a very good observation of the transit of *Venus* of December 6 with my 9-in. silver-on-glass Reflector by Calver; power used about 150. The definition was good, the rice grains being *very* distinctly visible a short time before the transit.

Latitude N.	...	...	52° 14′ +
Longitude W.	...	...	2 12 45

Clock 11ˢ fast.

Owing to clouds the first contact not seen.

	h m s	Corrected Time = −11ˢ. h m s
Dark limb of *Venus* first seen	2 2 45	2 2 34
Not half on limb of Sun	2 10 30	—
Half on limb of Sun	2 11 30	2 11 19
More than half	2 11 46	—
Venus wholly visible	2 14 30	2 14 19
Internal contact not taken place	2 20 0	—
The last appearance of any well marked discontinuity in the illumination in the limb of the Sun near point of contact	2 21 55	2 21 44
Internal contact over	2 22 4	—

The Mount, Worcester:
1882, *Dec.* 7.

Ephemeris of the Satellites of Uranus, 1883. By A. Marth.

The major and minor semiaxes a and b of the apparent ellipses described by the satellites, the angle of position P of the minor axes in the direction of superior conjunction, and the latitude of the Earth above the assumed plane of the orbits, are the following:—

Greenwich Noon.	*Ariel.* a_1	*Ariel.* b_1	*Umbriel.* a_2	*Umbriel.* b_2	*Titania.* a_3	*Titania.* b_3	*Oberon.* a_4	*Oberon.* b_4	P.	Lat. of Earth.
1883.	″	″	″	″	″	″	″	″	°	″
Jan. 9	14·83	+1·91	29·65	+2·66	33·88	+4·37	45·31	+5·84	285·52	+7·40
19	14·95	1·89	20·83	2·63	34·16	4·32	45·68	5·77	·51	7·26
29	15·06	1·84	20·98	2·56	34·42	4·21	46·02	5·63	·51	7·02
Feb. 8	15·15	1·77	21·11	2·47	34·63	4·05	46·31	5·42	·49	6·72
18	15·23	1·68	21·21	2·35	34·79	3·85	46·53	5·15	·48	6·35
28	15·27	1·58	21·28	2·20	34·90	3·62	46·67	4·84	·46	5·95
Mar. 10	15·29	1·47	21·31	2·05	34·95	3·36	46·73	4·50	·44	5·52
20	15·29	1·36	21·30	1·89	34·93	3·10	46·71	4·15	285·41	5·09
30	15·25	1·24	21·25	1·73	34·85	2·84	46·61	3·80	·39	4·68
Apr. 9	15·20	1·14	21·17	1·58	34·72	2·60	46·43	3·48	·36	4·29
19	15·11	1·04	21·06	1·45	34·54	2·38	46·19	3·19	·34	3·96
29	15·02	0·97	20·92	1·35	34·31	2·21	45·88	2·95	·32	3·69
May 9	14·90	0·91	20·76	1·27	34·05	2·08	45·53	2·78	·31	3·49
19	14·78	0·87	20·58	1·21	33·76	1·99	45·15	2·66	·30	3·38
29	14·65	+0·86	20·40	+1·19	33·46	+1·96	44·75	+2·62	285·29	+3·35

Longitudes $u-U$ of the satellites in their orbits reckoned from the points where they are at superior conjunction, and longitudes $U \pm 180°$ of the Earth, reckoned from the ascending node of the plane of the orbits on the plane of the equator:—

Greenwich Noon.	*Ariel.* u_1-U	Diff.	*Umbriel.* u_2-U	Diff.	*Titania.* u_3-U	Diff.	*Oberon.* u_4-U	Diff.	U.
1883.	°	1428°	°	868°	°	413°	°	267°	°
Jan. 9	249·34	·45	4·10	·74	52·84	·52	180·47	·39	5·52
19	237·79	·42	152·84	·72	106·36	·50	87·87	·38	5·55
29	226·21	·40	301·56	·69	159·86	·49	355·24	·36	5·59
Feb. 8	214·61	·37	90·25	·68	213·35	·48	262·60	·36	5·63
18	202·98	·34	238·93	·65	266·83	·47	169·96	·34	5·69
28	191·32	·31	27·58	·64	320·30	·46	77·30	·34	5·74
Mar. 10	179·63	·29	176·22	·63	13·76	·45	344·64	·33	5·80
20	167·92	·27	324·85	·61	67·21	·45	251·97	·33	5·86
30	156·19	·25	113·46	·61	120·66	·45	159·30	·34	5·92
Apr. 9	144·44	·24	262·07	·60	174·11	·45	66·64	·34	5·97
19	132·68	·23	50·67	·60	227·56	·45	333·98	·34	6·01
29	120·91	·22	199·27	·60	281·01	·46	241·32	·36	6·04
May 9	109·13	·22	347·87	·60	334·47	·47	148·68	·36	6·06
19	97·35	·23	136·47	·61	27·94	·48	56·04	·37	6·07
29	85·58		285·08		81·42		323·41		6·06

These values are to be interpolated for the times for which the positions of the satellites are required. The position-angles p and distances s from the centre of the planet are then found by means of the formulæ :—

$$s \sin (p - \mathrm{P}) = a \sin (u - \mathrm{U}),$$
$$s \cos (p - \mathrm{P}) = b \cos (u - \mathrm{U}).$$

The satellites move in the direction of increasing position-angles, and will be at their greatest elongations ("N" in position P + 90°, and "S" in position P − 90°), and at their superior (in position P) and inferior (in position P − 180°) conjunctions with the planet at or about the following hours, Greenwich Mean Time :—

Ariel.

	N.		S.		N.		S.		N.		S.	
1883.	h	d	h		h	d	h		h	d	h	
Jan. 7	21·2	9	3·5	Feb. 24	18·5	26	0·7	Apr. 13	15·8	14	22·1	
10	9·7	11	16·0	27	7·0	28	13·2	16	4·3	17	10·6	
12	22·2	14	4·4	Mar. 1	19·5	3	1·7	18	16·8	19	23·1	
15	10·7	16	16·9	4	8·0	5	14·2	21	5·3	22	11·6	
17	23·2	19	5·4	6	20·4	8	2·7	23	17·8	25	0·1	
20	11·7	21	17·9	9	8·9	10	15·2	26	6·3	27	12·6	
23	0·1	24	6·4	11	21·4	13	3·7	28	18·8	30	1·1	
25	12·6	26	18·9	14	9·9	15	16·2	May 1	7·3	2	13·5	
28	1·1	29	7·4	16	22·4	18	4·7	3	19·8	5	2·0	
30	13·6	31	19·8	19	10·9	20	17·2	6	8·3	7	14·5	
Feb. 2	2·1	3	8·3	21	23·4	23	5·6	8	20·8	10	3·0	
4	14·6	5	20·8	24	11·9	25	18·1	11	9·3	12	15·5	
7	3·1	8	9·3	27	0·4	28	6·6	13	21·8	15	4·0	
9	15·6	10	21·8	29	12·9	30	19·1	16	10·3	17	16·5	
12	4·0	13	10·3	Apr. 1	1·4	2	7·6	18	22·8	20	5·0	
14	16·5	15	22·8	3	13·9	4	20·1	21	11·3	22	17·5	
17	5·0	18	11·3	6	2·4	7	8·6	23	23·8	25	6·0	
19	17·5	20	23·7	8	14·9	9	21·1	26	12·2	27	18·5	
22	6·0	23	12·2	11	3·3	12	9·6	29	0·7	30	7·0	

Umbriel.

	N.		S.		N.		S.		N.		S.
1883.	h	d	h		h	d	h		h	d	h
Jan. 9	23·7	12	1·5	Feb. 24	13·8	26	15·5	Apr. 11	3·9	13	5·7
14	3·2	16	4·9	28	17·2	—		15	7·4	17	9·1
18	6·6	20	8·4	Mar. —		2	19·0	19	10·9	21	12·6
22	10·1	24	11·8	4	20·7	6	22·4	23	14·3	25	16·1
26	13·5	28	15·3	9	0·2	11	1·9	27	17·8	29	19·5
30	17·0	—		13	3·6	15	5·4	May 1	21·3	3	23·0
Feb. —		1	18·7	17	7·1	19	8·8	6	0·7	8	2·5
3	20·5	5	22·2	21	10·6	23	12·3	10	4·2	12	5·9
7	23·9	10	1·7	25	14·0	27	15·8	14	7·7	16	9·4
12	3·4	14	5·1	29	17·5	31	19·2	18	11·2	20	12·9
16	6·9	18	8·6	Apr. 2	21·0	4	22·7	22	14·6	24	16·4
20	10·3	22	12·0	7	0·5	9	2·2	26	18·1	28	19·8

Titania.

N. elong.		Inf. Conj.		S. elong.		Sup. Conj.	
1883.	h		h		h		h
Jan. 9	21·6	Jan. 12	1·8	Jan. 14	6·0	Jan. 16	10·3
18	14·5	20	18·7	22	23·0	25	3·3
27	7·4	29	11·7	31	15·9	Feb. 2	20·2
Feb. 5	0·4	Feb. 7	4·6	Feb. 9	8·9	11	13·1
13	17·4	15	21·6	18	1·8	20	6·1
20	10·3	24	14·6	26	18·8	28	23·0
Mar. 3	3·3	Mar. 5	7·5	Mar. 7	11·8	Mar. 9	16·0
11	20·3	14	0·5	16	4·7	18	9·0
20	13·2	22	17·5	24	21·7	27	2·0
29	6·2	31	10·4	Apr. 2	14·7	Apr. 4	18·9
Apr. 6	23·2	Apr. 9	3·4	11	7·7	13	11·9
15	16·1	17	20·4	20	0·6	22	4·9
24	9·2	26	13·4	28	17·6	30	21·8
May 3	2·1	May 5	6·3	May 7	10·6	May 9	14·8
11	19·1	13	23·3	16	3·5	8	7·8
20	12·0	22	16·3	24	20·5	27	0·7
29	5·0						

Oberon.

N. elong.			Inf. Conj.			S. elong.			Sup. Conj.		
1883.		h			h			h			h
		—	Jan.	8	23·6	Jan.	12	8·4	Jan.	15	17·1
Jan.	19	1·9		22	10·7		25	19·5		29	4·3
Feb.	1	13·1	Feb.	4	21·8	Feb.	8	6·6	Feb	11	15·4
	15	0·2		18	9·0		21	17·8		25	2·6
	28	11·4	Mar.	3	20·2	Mar.	7	5·0	Mar.	10	13·8
Mar.	13	22·6		17	7·4		20	16·2		24	1·0
	27	7·8		30	18·6	Apr.	3	3·4	Apr.	6	12·2
Apr.	9	21·0	Apr.	13	5·8		16	14·6		19	23·4
	23	8·2		26	16·9		30	1·7	May	3	10·5
May	6	19·3	May	10	4·1	May	13	12·9		16	21·7
	20	6·5		23	15·3		27	0·1		30	8·8